Open Access
J. Glob. Innov. Agric. Sci., 2023, 11(4):481-489
ISSN (Online): 2788-4546; ISSN (Print):2788-4538
DOI: https://doi.org/10.22194/JGIAS/11.1089
http://www.jgiass.com

Enhancing Wheat Crop Yield and Quality through Genetic Engineering Technologies: A Comprehensive Review

Usama Waheed [1], Zahida Iftikhar [2], Muhammad Mudassir [3], Swaiba Rani [4], Hassan Raza [5], Zahra Noor [6], Amina [7], Muhammad Hammad Butt [8], Hina Naveed [9], Sadaf Batool [10], Ali Hassan [11], Zia Ul Rehman [12] and Muhammad Naveed [13*]

Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan
*Corresponding author's e-mail: naveed.uaf01@gmail.com

The increasing world population has created an alarming situation to meet the demand for food. Ultimately wheat yield is required to be increased proportionally to the world's population. An estimated increase of 05 tonnes per hectare is direly needed from the current production of 3.3 tonnes by the end of 2050. To achieve this goal it is required to adopt new, emerging, and efficient breeding techniques which caused a recent breakthrough in wheat genome sequencing and provided sufficient information for the traits which are directly related to quality and yield of crops. This review provides a comprehensive overview of tools and techniques which are widely used for discovering the functionality of genes that results in specific phenotypes of Wheat. It gives a deep historical account of the development of wheat transformation techniques and provides an idea about in which way these techniques have been adapted to produce gain-of-function phenotypes through gene overexpression, loss-of-function phenotypes through the expression of antisense RNAs (RNA interference or RNAi). Recently, gene structure and expression manipulation using site-specific nucleases such as CRISPR/Cas9 for genome editing. The review summarizes recent successes in the application of wheat genetic manipulation to enhance yield, improve wheat's nutritional and health-promoting qualities, and boost the crop's resistance to various biotic and abiotic stresses.
Keywords: Transformation, gene knock-Out, gene knock-In, RNAI, overexpression.

INTRODUCTION

Wheat is the king of cereal crops. The cereal grain known as wheat is one of the most essential staple foods in many nations and is widely grown all over the world. It is a member of the grass family and belongs to the genus Triticum. It is thought that wheat originated in the Middle East's Fertile Crescent, where it has been grown for thousands of years (Liliane and Charle). The Middle East was the origin of wheat farming, which later extended to Europe, Africa, and Asia. The most frequently farmed cereal grain in the world today, wheat is grown on all continents save Antarctica. Wheat is a flexible crop that may be used to make a wide range of culinary products, including bread, pasta, cakes, biscuits, and many more (Varshney *et al.*, 2020). Moreover, it is utilized in the creation of biofuels and as animal feed. Its nutritional content varies based on its type and processing method (Steinwand and Ronald, 2020). Complex carbs, fiber, protein, and important vitamins and minerals may all be found in whole wheat. Wheat production is challenged by several causes, including soil degradation, pests and diseases, and climate change despite its significance as a food crop. To create new wheat types that are tougher and can endure these difficulties, scientists and farmers are collaborating. By adding desired features that are challenging or impossible to get via conventional breeding techniques, genetic engineering has the potential to significantly contribute to the improvement of wheat (Senapati *et al.*, 2019).The creation of wheat cultivars with increased pest and disease resistance is one area where genetic engineering can be especially helpful. Introducing genes that produce insecticidal proteins or improve the plant's inherent defensive systems can accomplish this (Henry *et al.*, 2016; Senapati *et al.*, 2019).The nutritional value of wheat may be increased by genetic engineering, which is another area where it might be useful.(Langridge, 2013). For instance, genes that boost the quantities of critical amino acids or

Waheed, U., Z. Iftikhar, M. Mudassir, S. Rani,H.Raza, Z. Noor, Amina, M. H. Butt, H. Naveed, S. Batool, A. Hassan, Z. Rehman and M. Naveed. 2023. Enhancing Wheat Crop Yield and Quality through Genetic Engineering Technologies: A Comprehensive Review. Journal of Global Innovations in Agricultural Sciences 11:481-489.
[Received 9 Jun 2023; Accepted 10 Aug 2023; Published 22 Dec 2023]

decrease the levels of allergenic proteins might be inserted. Moreover, wheat yields and resistance to environmental stresses including salt, heat, and drought can be improved by genetic engineering. This can be accomplished by adding genes to the plant that boost photosynthetic capacity or increase water usage effectiveness (Borisjuk *et al.*, 2019). Overall, genetic engineering has the potential to significantly increase the quality, productivity, and resilience of wheat crops, which might assist to fulfill the rising need for food while lowering the impact of agriculture on the environment (Manickavelu *et al.*, 2012). The safety and possible dangers of genetically modified crops must be thoroughly considered, and they must also be appropriately controlled and labeled. The need for food is rising everywhere as the world's population expands. There is no denying that there is still a food shortage in some areas (Daryanto *et al.*, 2016). Moreover, there are certain effects of population expansion on the climate, environment, and amount of arable land. Crop output will eventually be impacted by these variables. Even while eating is still a major issue, hidden hunger, or the body's inadequate intake of key nutrients and trace components, is still a significant issue. By 2050, it's predicted that there will be 10 billion people on the planet (Mwadzingeni *et al.*, 2016). Deliberate thought should thus be given to the difficulty of achieving the crop output and quality requirements of 10 billion people.Genetic engineering is the process of altering recipient cells' genetic makeup by utilizing contemporary biological tools to change their genomic DNA at the molecular level (Gupta *et al.*,2017). Herbicide-resistant tobacco was created in 1983, ushering in the age of plant genetic engineering, which was the first to use genetic engineering in plants. The first batch of transgenic crops was successfully grown commercially in 1996, and genetically modified crops started to appear on the market. Since that time, fast-advancing genetic engineering technologies have significantly improved agricultural yields and quality (Kumar *et al.*, 2020).The principles underlying several genetic engineering technologies are outlined in this review, with particular attention paid to the positive and negative impact of due gene editing technologies, along with defining a difference between transgenic technology and gene editing technology. A brief overview of recent research to enhance transformation and regeneration, and efficient use of GE technologies to improve crop yield and quality (Khalil, 2020). There is also a discussion of certain unresolved issues with genetic engineering technologies. Although conventional breeding techniques and genetic engineering have made tremendous progress in enhancing wheat, there are still several research gaps that need to be filled to further improve the crop's production, quality, and resilience. Understanding the genetic foundation of complex characteristics like yield, drought tolerance, and disease resistance is a crucial area where the study is required. This entails finding and describing the genes and genetic pathways that are responsible for these features, as well as creating instruments and techniques for precisely and purposefully modifying them (Friedmann and Roblin, 1972).The creation of more productive and environmentally friendly agricultural methods for the production of wheat is another area that calls for an investigation. This entails creating fresh approaches to crop management, enhancing soil quality, and using fewer agrochemicals. The social and economic aspects that affect the production and consumption of wheat also require further study (Xia *et al.*, 2022). This entails comprehending consumer requirements and preferences, creating markets for novel wheat products, and enhancing the living conditions of smallholder farmers who depend on the production of wheat for their livelihoods and food security. Overall, filling in these research gaps will be essential to ensure that wheat is a critical commodity that can be grown sustainably to feed the expanding world population (Wen *et al.*, 2022).

***Genetic engineering technology*:** The science of genetic engineering enables researchers to change the DNA of many living things, such as plants, animals, and microbes. It entails the application of cutting-edge methods for precise and regulated genetic material modification of an organism (Behl *et al.*, 2022). The recombinant DNA technique, which entails snipping and splicing DNA fragments from various sources and recombining them to produce new genetic sequences, is one of the main methods used in genetic engineering. (Patil *et al.*, 2022) This enables the deletion or modification of existing genes as well as the introduction of particular genes or genetic components into the genome of an organism. Gene editing, which includes making targeted alterations to particular genes using methods like CRISPR-Cas9, is another crucial tool in genetic engineering. This enables researchers to precisely alter a living thing's DNA sequence to treat disease-causing mutations or add advantageous characteristics. (Patil *et al.*, 2022) Several industries, including biotechnology, medicine, and agriculture, use genetic engineering. For instance, it is employed to create novel crop types with increased yields, pest and disease resistance, and resiliency to environmental stresses. Also, it aids in the creation of novel genetic disease therapies like gene therapy(Angon and Habiba, 2023). Even while genetic engineering has the potential to have many positive effects, there are worries about the possible dangers and moral ramifications of changing the genetic makeup of living things. As a result, many nations throughout the world have strong laws and monitoring that apply to the creation and use of (GMOs)(Gbashi *et al.*, 2021). European Union (EU): One of the most thorough and stringent regulation systems for GMOs is found in the EU. The European Food Safety Authority must conduct a thorough risk assessment of each GMO before its release into the environment or the market (EFSA). GMO-derived items must be labeled for customers to make educated decisions (Frieß *et al.*, 2023). United States: The Food and Drug Administration (FDA), the

Environmental Protection Agency (EPA), and the United States Department of Agriculture all have jurisdiction over GMOs in the US (USDA). Before commercial distribution, GMO developers must undergo a comprehensive safety review, despite claims from detractors that the regulatory procedure is less stringent than in the EU (Kuzma, 2023). Brazil: Brazil is one of the leading agricultural producers and has implemented a strict legal framework for GMOs. The National Technical Commission on Biosafety (CTNBio) oversees the approval process for GMOs, and strict labeling requirements are enforced (Tachikawa and Matsuo, 2023).Japan: The Cartagena Protocol on Biosafety sets very stringent rules for GMOs in Japan. GMO-derived product labeling is required (Spök *et al.*, 2022). Australia: Australia's Office of the Gene Technology Regulator oversees the country's extensive GMO regulation framework (OGTR). GMOs are subject to thorough testing, and there are particular labeling regulations in place (Jones *et al.*, 2022).

Transgenic technology**:** The process of genetic engineering known as "transgenic technology" entails inserting foreign DNA into an organism's genome. This makes it possible to change, deletion of existing genes, or totally introduction of a new gene or part of the gene into the genome (Osmond and Colombo, 2019). Recombinant DNA technology is often used in transgenic technology to insert an alien DNA sequence into an organism's genome. A vector, a carrier molecule that can carry the foreign DNA sequence into the cells of the organism, can be used to do this (Osmond and Colombo, 2019). The creation of genetically modified organisms (GMOs) for use in agriculture is one of the most often used transgenic technology applications. To bestow desired qualities, like insect resistance or tolerance to environmental stresses, this entails inserting new genes into agricultural plants. Biotechnology and medicine are other fields where transgenic technology is used (Ozyigit *et al.*, 2021). It may be utilized, for instance, to make therapeutic proteins or create fresh remedies for hereditary illnesses. Although transgenic technology has the potential to have many positive effects, there are also worries about the possible dangers and moral ramifications of tampering with living things' genetic makeup(Singh, 2022). As a result, many nations throughout the world have strong laws and control that apply to the creation and use of transgenic organisms. The world's population will exceed 9 billion by the middle of the twenty-first century, making it extremely difficult to feed (Holman, 2019). The difficulty is increased by the consequences of climate change, which include rising temperatures, water shortage, and flooding. Increased stress tolerance in genetically modified crop types might enable crops to better respond to changing environmental circumstances. Soybean, maize, cotton, and rapeseed have all benefited greatly from this biotechnology in terms of increased resilience to biotic and abiotic stressors (Li *et al.*, 2021b). Novel crop species generated through genetic engineering are now widely planted in many nations, providing farmers with substantial advantages while safeguarding the environment. One of the most crucial crops for human existence, particularly in Asia, is wheat, which is crucial for social stability, economic growth, food security, human health, and nutrition. Due to its complicated genome, a large number of repetitive DNA sequences, and poor capacity for plant regeneration, wheat's adoption of genetic modification technologies has lagged behind that of other significant cereal crops (Ansari *et al.*, 2020). Although conventional breeding methods are time-consuming, new wheat varieties have been created primarily through them since transgenic wheat has not yet been sold in fields. The total annual wheat output has not grown in recent years and will not be enough to meet the escalating market demand. To refine and use innovative breeding approaches based on the molecular understanding of factors associated with grain yield (Ansari *et al.*, 2020). During the past 30 years, there has been steady advancement in wheat genetic engineering technology. While the efficiency had been extremely poor before then, acquired the first example of transgenic wheat plants via high-velocity microprojectile bombardment, started the process of conventional transformation of wheat (Ceccon *et al.*, 2020). Using immature embryos, wheat transformation efficiency has significantly increased in recent years. As an illustration, the Japan Tobacco Company created the Pure. Wheat technology, an effective transformation mechanism. A transformation efficiency (TE) of around 45.0% was obtained using this method for several Australian wheat cultivars; fifteen commercial Chinese wheat types were also successfully changed with an efficiency of up to 40.0% (Rasheed *et al.*, 2023).

Gene editing technology**:** A sort of genetic engineering known as gene editing enables researchers to precisely alter particular DNA sequences that are present in an organism's genome. Nucleases are enzymes that can be designed to cleave DNA at precise sites, and they are used in this technique. CRISPR-Cas9 is one of the most used methods for gene editing (Zarei *et al.*, 2019). It makes use of a guide RNA molecule that can attach to a particular DNA sequence and a nuclease called Cas9 that can cut the DNA at that point. Scientists may precisely alter the genome of an organism by inserting a changed or repaired DNA sequence, such as fixing disease-causing mutations or adding advantageous features (Ghosh *et al.*, 2021). Several industries, including biotechnology, medicine, and agriculture, can benefit from gene editing technologies. It may be used, for instance, to create novel crop types with increased yields, pest and disease resistance, and tolerance to environmental stresses. New medicines for hereditary illnesses like sickle cell anemia and cystic fibrosis can also be created using it. Although the use of gene editing technology has the potential to have many positive effects. There are also worries about the possible dangers and moral ramifications of changing the genetic

makeup of living things (Pushpa and Dev, 2023). As a result, many nations throughout the world have strong laws and control that apply to the creation and use of gene-edited species (Khan *et al.*, 2023). Faster wheat improvement and sustainable wheat production are made possible by the precise substitution of an existing allele by HDR. Although precise gene/allele replacement or gene targeting is now possible in Arabidopsis and some crop species, including rice, maize, and tomato (Li and Xia, 2020). So, it is necessary to continue developing various ways to increase HDR effectiveness to promote wheat improvement by precise genome editing (Van Vu *et al.*, 2019). Given the importance of HDR, it is possible to examine several strategies that have been employed to increase HDR efficiency in mammalian cells or other plant species in wheat. First, an enrichment of DRT availability using a modular RNA aptamer-streptavidin technique enhanced HDR efficiency in human cells to values that were 18 times greater than those achieved using the traditional approach (Chen *et al.*, 2022). Also, by increasing the number of DRTs in the nucleus, spatial and temporal co-localization of the Cas9 protein and DRTs via a SNAP-tag boosted HDR effectiveness by a factor of 24. Second, if the DRT is close to the DSB, HDR efficiency can be increased) (Verma *et al.*, 2022). For instance, by covalently attaching a single-stranded donor oligonucleotide (ssODN) to the Cas9/guide RNA ribonucleoprotein (RNP) complex via a fused HUH endonuclease 5, HDR effectiveness was enhanced by 30 times (Naveed *et al.*, 2022). Finally, given that HDR occurs often in egg cells and early embryos, using the DD45 gene promoter to induce SpCas9 expression in Arabidopsis has the potential to boost the effectiveness of HDR-mediated genome editing. Finally, a tandem repeat-HDR (TR-HDR) strategy has recently been developed for fragment replacement and seamless in-locus tagging of either the N- or C-terminal end of proteins with a flag tag of up to 130 bp in rice. This method involves the random insertion of a phosphorothioate-linkage and phosphorylation-modified DNA fragment (Li *et al.*, 2021a). We anticipate that in the long run, precise gene/allele replacement will be accomplished in wheat using the CRISPR/Cas system and will be widely used to generate novel germplasm and breed elite wheat varieties. This expectation is based on technological advancements in mammalian cells and other plant species, as well as manipulations of diverse modules to enhance HDR efficacy (Zhang *et al.*, 2019).

***Effects of gene editing technology, gene knock-out*:** Gene knockout is a genetic method for "knocking out" or inactivating" a particular gene by interfering with its production or function in an organism (Zhang *et al.*, 2021). This is often accomplished by introducing synthetic DNA constructs into cells, which can result in mutations that can stop the target gene from making a useful protein. The creature that results from the gene knockout is next investigated to ascertain the gene's function and its part in numerous biological processes (Wang *et al.*, 2023). The ability to study the activities of certain genes, their connections with other genes, and their participation in disease processes have made gene knockout technology a crucial tool in genetics research. Gene knockout may be accomplished using a variety of techniques, including homologous recombination, RNA interference (RNAi), and gene editing tools like CRISPR-Cas9 (Khalil, 2020). The method may also be utilized in agricultural and scientific research. It is frequently employed in model organisms including mice, fruit flies, and zebrafish. Significant variations in yield, grain quality, nutrient usage effectiveness, resilience to both abiotic and biotic stressors, and other agriculturally relevant features can be attributed to allelic variants in crops. SNPs or the insertion or deletion of a gene fragment are the main genetic changes that result in the valuable alleles obtained from local landraces or wheat relatives (Mei *et al.*, 2022). It can take up to ten years to introduce elite alleles into commercial cultivars through crossing and back-crossing. The simultaneous development of HDR, base editing, knockout modules, or combinations thereof will allow for the simultaneous alteration of numerous loci, pyramiding several advantageous alleles into a marketable variety in a short amount of time (Chen and Liu, 2022). The complicated agronomic features of wheat would benefit greatly from this. We anticipate that in the future it will be possible to design and breed "Green Super Wheat" with high yields, high nutritional values, resistance to bovine spongiform encephalopathy (BSE), and other traits thanks to the development of next-generation DNA sequencing technologies, the availability of complete wheat genome sequences and pan-genome data (Ansai and Kitano, 2022).

***Gene knock-in*:** In contrast to gene knockout, which inactivates an existing gene, gene knock-in introduces new genes into the genome of an organism. Gene knock-in can be used to add desired features like as disease resistance, stress tolerance, or increased yield and grain quality into wheat varieties (Bansal *et al.*, 2022). The process of producing gene knock-in in wheat may be accomplished gene knock-in in wheat may be accomplished via a variety of techniques, including biolistic transformation, Agrobacterium-mediated transformation, and gene editing technologies like CRISPR-Cas9, TALENs, and Zinc Finger Nucleases (ZFNs). gene knock-in in wheat may be accomplished via a variety of techniques, including biolistic transformation, Agrobacterium-mediated transformation, and gene editing technologies like CRISPR-Cas9, TALENs, and Zinc Finger Nucleases (ZFNs) (Ansari *et al.*, 2020). For instance, scientists have introduced a gene from a wild cousin of wheat that gives resistance to powdery mildew, a prevalent fungal disease, using CRISPR-Cas9 genome editing. The resistance gene was inserted into the wheat genome using CRISPR-Cas9, giving wheat plants increased resistance to powdery mildew. The insertion of genes related to drought tolerance

into wheat is another instance of gene knock-in (Wang *et al.*, 2020). A gene producing a drought-tolerant protein from a similar species of wheat was inserted into commercial wheat types through biolistic transformation. The resultant wheat plants had greater resistance to drought and produced more grain when there was less water available. The production of novel wheat varieties with enhanced features that can help growers, consumers, and the environment are just a few of the possible advantages of gene knock-in for wheat enhancement (Dey, 2021). However, like with all genetic engineering methods, the use of gene knock-in in wheat is governed and closely monitored to ensure that it is secure and does not present any hazards to the environment or human health (Kadam *et al.*, 2023).

Gene-regulation**:** The majority of our understanding of the biological mechanisms underlying plant NUE comes from model plant species. Wheat does not, for the most part, have the critical genes for N metabolism that were discovered in model plants (Lin *et al.*, 2022). The improvement of wheat NUE is hampered by low genetic variety; one approach is to investigate wild relatives and ancient germplasm (York *et al.*, 2022). The potential genes for effective wheat NUE enhancement include genes that regulate N absorption and metabolism. High nitrogen applications intended to boost crop output are outweighed by greater production costs and detrimental effects on the environment. Just one-third of the nitrogen given to wheat is used, indicating room for improvement in nitrogen use efficiency (NUE) (Duan *et al.*, 2023). The intricacy of the characteristic, which includes processes related to nitrogen intake, transport, reduction, assimilation, translocation, and remobilization, makes it difficult to achieve higher NUE. Hence, understanding how these activities are regulated genetically is essential to boosting NUE. Although primary nitrogen uptake and genes associated with metabolism have been extensively examined, it is still unclear how much of an impact each gene has on NUE (Tian *et al.*, 2022). Current research has concentrated on identifying miRNAs that affect the expression of particular NUE-related genes and designing transcription factors. It is necessary to apply the knowledge gained from model species to wheat utilizing recently made available whole genome sequences, as well as by looking at genetic variations of NUE-related variables in wild relatives and ancient germplasm. Current research suggests that NUE has a complicated genetic foundation. The most efficient way to obtain a decent level of NUE in the field will be to pyramid different genes (Katz *et al.*, 2022).

Application of zinc finger nucleases (ZFNs)**:** Wheat has been improved using zinc finger nucleases (ZFNs), a sort of gene editing technique, by making precise alterations to its DNA sequence (Li *et al.*, 2022). ZFNs are designed proteins that enable precision gene editing by recognizing and cutting certain DNA sequences. ZFNs have been used to modify the genes in wheat that are responsible for features including disease resistance, yield, and grain quality (Raza *et al.*, 2022). For instance, to create wheat types that are better tolerated by patients with celiac disease or gluten sensitivity, scientists have modified genes involved in the synthesis of gluten proteins in wheat using ZFNs. To bestow desired qualities on wheat, such as insect resistance or tolerance to environmental stresses, additional genes have also been inserted using ZFNs (Vyshnavi and Dawar, 2022). For instance, scientists have introduced a gene from a wild cousin of wheat using ZFNs that provides resistance to the prevalent fungal disease powdery mildew. Overall, the use of ZFNs to improve wheat has the potential to offer a variety of advantages, including the creation of new wheat varieties with enhanced quality, resilience, and yields. ZFNs are used in wheat, but like other gene editing technologies, they are subject to tight guidelines and inspection to make sure they are secure and don't endanger either human health or the environment. The creation of wheat cultivars with lower amounts of gluten proteins is one example of wheat improvement by Zinc Finger Nucleases (ZFNs) (Das *et al.*, 2023). Those with celiac disease or gluten sensitivity may experience digestive problems from the protein complex called gluten, which is present in wheat and other grains (Lim *et al.*, 2022). To create wheat types with lower amounts of gluten, scientists have modified genes that govern the synthesis of gluten proteins in wheat using ZFNs. To create wheat types that contain fewer immunogenic gluten proteins, scientists have made precise alterations to the DNA sequence of these genes. Enabling patients to consume wheat-based goods with lower quantities of gluten, this strategy may help persons with celiac disease or gluten sensitivity (Gosavi *et al.*, 2022). Also, it may help the food business by offering a fresh source of components for the creation of gluten-free goods. The creation of wheat cultivars with enhanced disease resistance is another example of wheat enhancement by ZFNs (Nasrallah *et al.*, 2022). New genes that impart resistance to ailments like powdery mildew and stripe rust, which may result in severe output losses in wheat crops, have been inserted into wheat using ZFNs by researchers. Researchers have been able to create wheat varieties with greater disease resistance and higher yields by inserting these disease-resistant genes into commercial wheat cultivars. Farmers may gain from this if crop losses are decreased and production is increased (Reddy *et al.*, 2022).

Comparative analysis of transgenic and gene editing technologies**:** Two crucial genetic engineering methods utilized for crop development are transgenic technology and gene editing. Even though both methods entail altering an organism's genetic composition, they have certain key differences (Musunuru, 2022). The following are some significant distinctions between gene editing and transgenic technology: Gene editing modifies already-existing genes or DNA sequences inside an organism's genome, whereas transgenic technology involves transferring new genes or DNA sequences from one creature into another (Chowdhury

et al., 2022). Although transgenic technology may introduce many genes and their regulatory components, gene editing enables more precise and focused modifications to be applied to certain genes or Genomic regions. Precision: Compared to transgenic technologies, gene editing is typically thought to be more accurate (Mani *et al.,* 2023). The transgenic technique involves adding new genes into the genome at random sites, whereas gene editing methods like CRISPR-Cas9 may target particular genes or regions within the genome with great accuracy (Wang *et al.,* 2022). On the genome and gene expression patterns of the organism, this may have unforeseen consequences. Regulation: Gene editing is not as subject to regulation as transgenic technologies (Chan *et al.,* 2022). Before being made available for commercial use, transgenic crops are frequently regarded as genetically modified organisms (GMOs) and are subject to regulatory review by government organizations. Contrarily, the regulatory frameworks for the use of gene editing are still being built in many nations since it is thought to be a more recent and less well-defined technology. Acceptance by the general public (Hussin *et al.,* 2022). For many years, the safety of genetically modified crops and their possible effects on the environment and human health have been hotly debated topics. Some people believe that gene editing, which does not entail adding genes from other organisms into the genome, is a more acceptable kind of genetic engineering(Hussin *et al.,* 2022). In conclusion, both gene editing and transgenic technologies have the potential to enhance crops, but they differ in the degree of genetic modifications, level of accuracy, regulatory monitoring, and level of public acceptance. While transgenic technology has been around for a while and is more closely regulated, gene editing offers a more focused and accurate method of genetic manipulation (Platani *et al.,* 2022).

***Use of genetic engineering to increase agricultural yield and quality*:** Gene editing using CRISPR/Cas9 technology has been applied to various crops, resulting in improved agricultural traits. For example, in rice, the OsAAP6 gene was knocked down to promote tillering and increase production. Wheat quality was enhanced by editing the Ppo gene to alter polyphenol oxidase expression. Decreasing the amylose content in rice was achieved by modifying the Wx gene, impacting rice quality. Multiple gene knockouts in rice, targeting GW2, GW5, and TGW6, improved grain traits and yield . In maize, altering both ZmBADH2a and ZmBADH2b genes resulted in aromatic popcorn. Using Cas protein variations, researchers developed new methods to enhance crop development. Additionally, editing the Wx protein intermediate domain in rice resulted in soft rice varieties. These gene editing techniques hold the potential to increase agricultural productivity and quality.

***Conclusion*:** As a potent tool for wheat enhancement, genetic engineering now allows researchers to add desirable features to the wheat genome and improve the crop's resistance to disease, environmental stress, and climate change. The area of genetic engineering has undergone a revolution with the introduction of gene editing tools like CRISPR-Cas9, TALENs, and Zinc Finger Nucleases (ZFNs), which have made it simpler, quicker, and more accurate to alter the wheat genome. Researchers have genetically modified commercial wheat types to include genes for disease resistance, increased yield, and drought tolerance, creating new wheat cultivars that are better suited to farmers' and consumers' evolving requirements. Genetically modifying wheat might have unforeseen consequences for the environment or human health, as with any developing technologies, and these risks and uncertainties need to be carefully assessed and handled through adequate regulatory monitoring. Overall, wheat genetic engineering has the potential to have many positive effects, such as greater crop output, improved nutritional value, and decreased usage of pesticides and other chemicals for weedicide i.e. (Sakura). Genetic engineering is projected to become more crucial as the world's population continues to rise and climate change presents new difficulties for agriculture. This will help to ensure food security and sustainable agriculture for the next generations.

***Authors contributions statement*:** Waheed, U., Iftikhar, Z., Mudassir, M., Rani, S., Raza have collected content and H., Noor, Z., Amina, Hammad Butt, M., Naveed, H., Batool, S., Hassan, A., Rehman, Z. U., & Naveed, M managed references and proofread the manuscript.

***Conflict of interest*:** The authors declare no conflict of interest.

***Acknowledgement*:** We are thankful to U.Waheed for reviwed and finalized the draft.

***Funding*:** All the authors contribute for funding.

***Ethical statement*:** This article does not contain any studies regarding human or animal.

***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere?

***Code availability*:** Not applicable.

***Consent to participate*:** All authors participated in this research study.

***Consent for publication*:** All authors submitted consent to publish this research. article in JGIAS.

REFERENCES

Angon, P.B.and U. Habiba. 2023. Application of the CRISPR/Cas9 Gene-editing System and Its Participation in Plant and Medical Science. CURRENT applied science and technology:10.55003/cast. 52022.55003. 55023.55003 (55013 pages)- 55010.55003/cast. 52022.55003. 55023.55003 (55013 pages).

Ansai, S.and J. Kitano. 2022. Speciation and adaptation research meets genome editing. Philosophical Transactions of the Royal Society B 377:20200516.

Ansari, W.A., S.U. Chandanshive, V. Bhatt, A.B. Nadaf, S. Vats, J.L. Katara, H. Sonahand R. Deshmukh. 2020. Genome editing in cereals: approaches, applications and challenges. International Journal of Molecular Sciences 21:4040.

Bansal, K., K. Mollaand V. Chinuusamy. 2022. Genome editing: a boon for plant biologists, breeders, and farmers. Curr. Sci. 123:15-19.

Behl, T., I. Kaur, A. Sehgal, S. Singh, N. Sharma, S. Bhatia, A. Al-Harrasiand S. Bungau. 2022. The dichotomy of nanotechnology as the cutting edge of agriculture: Nano-farming as an asset versus nanotoxicity. Chemosphere 288:132533.

Borisjuk, N., O. Kishchenko, S. Eliby, C. Schramm, P. Anderson, S. Jatayev, A. Kurishbayevand Y. Shavrukov. 2019. Genetic modification for wheat improvement: from transgenesis to genome editing. BioMed Research International 2019

Ceccon, C.C., A. Caverzan, R. Margis, J.R. Salvadoriand M.F. Grando. 2020. Gene stacking as a strategy to confer characteristics of agronomic importance in plants by genetic engineering. Ciência Rural 50

Chan, Y.-T., Y. Lu, J. Wu, C. Zhang, H.-Y. Tan, Z.-x. Bian, N. Wangand Y. Feng. 2022. CRISPR-Cas9 library screening approach for anti-cancer drug discovery: overview and perspectives. Theranostics 12:3329.

Chen, J., S. Li, Y. He, J. Liand L. Xia. 2022. An update on precision genome editing by homology-directed repair in plants. Plant Physiology 188:1780-1794.

Chen, P.J.and D.R. Liu. 2022. Prime editing for precise and highly versatile genome manipulation. Nature Reviews Genetics:1-17.

Chowdhury, N., D. Das, Y.N. Sarki, M. Sharma, D.L. Singhaand C. Chikkaputtaiah. 2022. Genome Editing and CRISPR-Cas Technology for Enhancing Abiotic Stress Tolerance in Cereals, Omics Approach to Manage Abiotic Stress in Cereals. Springer pp. 259-294.

Daryanto, S., L. Wangand P.-A. Jacinthe. 2016. Global synthesis of drought effects on maize and wheat production. PloS one 11:e0156362.

Das, N., D. Ghosh Dharand P. Dhar. 2023. Editing the genome of common cereals (Rice and Wheat): techniques, applications, and industrial aspects. Molecular Biology Reports 50:739-747.

Dey, A. 2021. CRISPR/Cas genome editing to optimize pharmacologically active plant natural products. Pharmacological Research 164:105359.

Duan, Y., H. Yang, H. Yang, Y. Wu, S. Fan, W. Wu, L. Lyuand W. Li. 2023. Integrative physiological, metabolomic and transcriptomic analysis reveals nitrogen preference and carbon and nitrogen metabolism in blackberry plants. Journal of Plant Physiology 280:153888.

Friedmann, T.and R. Roblin. 1972. Gene Therapy for Human Genetic Disease? Proposals for genetic manipulation in humans raise difficult scientific and ethical problems. Science 175:949-955.

Frieß, J.L., C.R. Lalyer, B. Giese, S. Simonand M. Otto. 2023. Review of gene drive modelling and implications for risk assessment of gene drive organisms. Ecological Modelling 478:110285.

Gbashi, S., O. Adebo, J.A. Adebiyi, S. Targuma, S. Tebele, O.M. Areo, B. Olopade, J.O. Odukoyaand P. Njobeh. 2021. Food safety, food security and genetically modified organisms in Africa: a current perspective. Biotechnology and Genetic Engineering Reviews 37:30-63.

Ghosh, D., A. Kumarand N. Sinha. 2021. Targeted genome editing: a new era in molecular biology, Advances in animal genomics. Elsevier. p. 75-89.

Gosavi, G., B. Ren, X. Li, X. Zhou, C. Spetzand H. Zhou. 2022. A new era in herbicide-tolerant crops development by targeted genome editing. ACS Agricultural Science & Technology 2:184-191.

Gupta, P.K., H.S. Balyanand V. Gahlaut. 2017. QTL analysis for drought tolerance in wheat: present status and future possibilities. Agronomy 7:5.

Henry, R.J., P. Ranganand A. Furtado. 2016. Functional cereals for production in new and variable climates. Current Opinion in Plant Biology 30:11-18.

Holman, C.M. 2019. A fractured international response to CRISPR-enabled gene editing of agricultural products. Biotechnology law report 38:3-23.

Hussin, S.H., X. Liu, C. Li, M. Diaby, G.H. Jatoi, R. Ahmed, M. Imranand M.A. Iqbal. 2022. An Updated Overview on Insights into Sugarcane Genome Editing via CRISPR/Cas9 for Sustainable Production. Sustainability 14:12285.

Jones, M.G., J. Fosu-Nyarko, S. Iqbal, M. Adeel, R. Romero-Aldemita, M. Arujanan, M. Kasai, X. Wei, B. Prasetyaand S. Nugroho. 2022. Enabling trade in gene-edited produce in Asia and Australasia: The developing regulatory landscape and future perspectives. Plants 11:2538.

Kadam, S., D. Leeand P. Dhiman. 2023. Genome-Editing Approaches for Biofortification of Cereal Crops. Biofortification in Cereals: Progress and Prospects:93-126.

Katz, E., A. Knapp, M. Lensink, C.K. Keller, J. Stefani, J.-J. Li, E. Shane, K. Tuermer-Lee, A.J. Bloomand D.J. Kliebenstein. 2022. Genetic variation underlying differential ammonium and nitrate responses in Arabidopsis thaliana. The Plant Cell 34:4696-4713.

Khalil, A.M. 2020. The genome editing revolution. Journal of genetic engineering and biotechnology 18:1-16.

Khan, Z., S.H. Khan, A. Ahmed, M.U. Iqbal, M.S. Mubarik, M.Z. Ghouri, F. Ahmad, S. Yaseen, Z. Aliand A.A. Khan. 2023. Genome editing in cotton: challenges and opportunities. Journal of Cotton Research 6:1-21.

Kumar, K., G. Gambhir, A. Dass, A.K. Tripathi, A. Singh, A.K. Jha, P. Yadava, M. Choudharyand S. Rakshit. 2020. Genetically modified crops: current status and future prospects. Planta 251:1-27.

Kuzma, J. 2023. Social Concerns and Regulation of Cisgenic Crops in North America, Cisgenic Crops: Safety, Legal and Social Issues. Springer pp. 179-194.

Langridge, P. 2013. Wheat genomics and the ambitious targets for future wheat production. Genome 56:545-547.

Li, S.and L. Xia. 2020. Precise gene replacement in plants through CRISPR/Cas genome editing technology: current status and future perspectives. Abiotech 1:58-73.

Li, S., C. Zhang, J. Li, L. Yan, N. Wangand L. Xia. 2021a. Present and future prospects for wheat improvement through genome editing and advanced technologies. Plant Communications 2:100211.

Li, Y., Z. Jia, S. Zhangand X. He. 2021b. Progress in gene-editing technology of zebrafish. Biomolecules 11:1300.

Li, Y., X. Wu, Y. Zhangand Q. Zhang. 2022. CRISPR/Cas genome editing improves abiotic and biotic stress tolerance of crops. Frontiers in Genome Editing 4

Liliane, T.N.and M.S. Charles. 2020. Factors affecting yield of crops. Agronomy-climate change & food security:9.

Lim, K., S.-I. Choand J.-S. Kim. 2022. Nuclear and mitochondrial DNA editing in human cells with zinc finger deaminases. Nature Communications 13:366.

Lin, S., Z. Chen, T. Chen, W. Deng, X. Wanand Z. Zhang. 2022. Theanine metabolism and transport in tea plants (Camellia sinensis L.): advances and perspectives. Critical Reviews in Biotechnology 1-15.

Mani, S., D. Jindaland M. Singh. 2023. Gene Therapy, A Potential Therapeutic Tool for Neurological and Neuropsychiatric Disorders: Applications, Challenges and Future Perspective. Current Gene Therapy 23:20-40.

Manickavelu, A., K. Kawaura, K. Oishi, T. Shin-I, Y. Kohara, N. Yahiaoui, B. Keller, R. Abe, A. Suzukiand T. Nagayama. 2012. Comprehensive functional analyses of expressed sequence tags in common wheat (Triticum aestivum). DNA research 19:165-177.

Mei, F., B. Chen, L. Du, S. Li, D. Zhu, N. Chen, Y. Zhang, F. Li, Z. Wangand X. Cheng. 2022. A gain-of-function allele of a DREB transcription factor gene ameliorates drought tolerance in wheat. The Plant Cell 34:4472-4494.

Musunuru, K. 2022. Moving toward genome-editing therapies for cardiovascular diseases. The Journal of Clinical Investigation 132

Mwadzingeni, L., H. Shimelis, E. Dube, M.D. Laingand T.J. Tsilo. 2016. Breeding wheat for drought tolerance: Progress and technologies. Journal of Integrative Agriculture 15:935-943.

Nasrallah, A., E. Sulpice, F. Kobaisi, X. Gidroland W. Rachidi. 2022. CRISPR-Cas9 Technology for the Creation of Biological Avatars Capable of Modeling and Treating Pathologies: From Discovery to the Latest Improvements. Cells 11:3615.

Naveed, M., J. Javed, U. Waheed, M. Sajid, M. Ijaz, A. Sehar, M. Attiqueand S. Javed. 2022. The role of CRISPR/Cas9 for genetic advancement of soybean: a review. Asian Journal of Biotechnology and Genetic Engineering 5:75-88.

Osmond, A.T.and S.M. Colombo. 2019. The future of genetic engineering to provide essential dietary nutrients and improve growth performance in aquaculture: Advantages and challenges. Journal of the World Aquaculture Society 50:490-509.

Ozyigit, I.I., H. Canand I. Dogan. 2021. Phytoremediation using genetically engineered plants to remove metals: a review. Environmental Chemistry Letters 19:669-698.

Patil, R., A. Sivaramand N. Patil. 2022. Gene Isolation Methods: Beginner’s Guide, A Complete Guide to Gene Cloning: From Basic to Advanced. Springer. p. 43-55.

Platani, M., O. Sokefun, E. Bassiland Y. Apidianakis. 2022. Genetic engineering and genome editing in plants, animals and humans: Facts and Myths. Gene:147141.

Pushpa, K.and S.I. Dev. 2023. Over View Of Gene Editing Technology And Its Application To Produce Designer Babies: 10.2478/bjlp-2023-0000043. Baltic Journal of Law & Politics 16:515-523.

Rasheed, A., S. Parveen, M. Afzaal, B. Niaz, F. Saeed, M. Hussain, A. Yasmin, A. Qamar, H. Ateeqand M.A. Raza. 2023. Exploring biochemical profile, antioxidant activity and structural properties of Bulgur prepared from traditional and autoclave methods. International Journal of Food Properties 26:274-289.

Raza, S.H.A., A.A. Hassanin, S.D. Pant, S. Bing, M.Z. Sitohy, S.A. Abdelnour, M.A. Alotaibi, T.M. Al-Hazani, A.H. Abd El-Azizand G. Cheng. 2022. Potentials, prospects and applications of genome editing technologies in livestock production. Saudi Journal of Biological Sciences 29:1928-1935.

Reddy, S., K.R. SGPand S. Palakurthy. 2022. Gene Knockout: Is it Like Bandwagon in Plant Breeding. Agricultural Biotechnology 75:3.

Senapati, N., P. Stratonovitch, M.J. Pauland M.A. Semenov. 2019. Drought tolerance during reproductive development is important for increasing wheat yield potential under climate change in Europe. Journal of experimental botany 70:2549-2560.

Singh, A.K. 2022. Gene Transfer Technique in Plant Callus and Selection of Transformants. Eduzone: International Peer Reviewed/Refereed Multidisciplinary Journal 11:290-296.

Spök, A., T. Sprink, A.C. Allan, T. Yamaguchiand C. Dayé. 2022. Towards social acceptability of genome-edited plants in industrialised countries? Emerging evidence from Europe, United States, Canada, Australia, New Zealand, and Japan. Frontiers in Genome Editing 4:899331.

Steinwand, M.A.and P.C. Ronald. 2020. Crop biotechnology and the future of food. Nature Food 1:273-283.

Tachikawa, M.and M. Matsuo. 2023. Divergence and convergence in international regulatory policies regarding genome-edited food: How to find a middle ground. Frontiers in Plant Science 14:1105426.

Tian, X., X. Xia, D. Xu, Y. Liu, L. Xie, M.A. Hassan, J. Song, F. Li, D. Wangand Y. Zhang. 2022. Rht24b, an ancient variation of TaGA2ox-A9, reduces plant height without yield penalty in wheat. New Phytologist 233:738-750.

Van Vu, T., Y.W. Sung, J. Kim, D.T.H. Doan, M.T. Tranand J.-Y. Kim. 2019. Challenges and perspectives in homology-directed gene targeting in monocot plants. Rice 12:1-29.

Varshney, R.K., P. Sinha, V.K. Singh, A. Kumar, Q. Zhangand J.L. Bennetzen. 2020. 5Gs for crop genetic improvement. Current Opinion in Plant Biology 56:190-196.

Verma, A.K., S. Mandal, Y. Serin, M.H. Ali, A. Tiwari, E. Lionettiand C. Catassi. 2022. CRISPR/Cas9 as a promising genome-editing technology for generating low-immunogenic wheat variety: recent legislation and global implementation of genetically engineered crops. CABI Reviews

Vyshnavi, R.and K.B.P. Dawar. 2022. Genome Editing: The Next Generation Breeding Strategy. Technologies:91.

Wang, K., Q. Gongand X. Ye. 2020. Recent developments and applications of genetic transformation and genome editing technologies in wheat. Theoretical and Applied Genetics 133:1603-1622.

Wang, S.-W., C. Gao, Y.-M. Zheng, L. Yi, J.-C. Lu, X.-Y. Huang, J.-B. Cai, P.-F. Zhang, Y.-H. Cuiand A.-W. Ke. 2022. Current applications and future perspective of CRISPR/Cas9 gene editing in cancer. Molecular Cancer 21:1-27.

Wang, Y., C. Liu, X. Qiao, X. Hanand Z.-P. Liu. 2023. PKI: A bioinformatics method of quantifying the importance of nodes in gene regulatory network via a pseudo knockout index. Biochimica et Biophysica Acta (BBA)-Gene Regulatory Mechanisms 1866:194911.

Wen, C., W. Dong, Q. Zhang, N. Heand T. Li. 2022. A system dynamics model to simulate the water-energy-food nexus of resource-based regions: A case study in Daqing City, China. Science of the Total Environment 806:150497.

Xia, F., Y. Yang, S. Zhang, D. Li, W. Sunand Y. Xie. 2022. Influencing factors of the supply-demand relationships of carbon sequestration and grain provision in China: Does land use matter the most? Science of The Total Environment 832:154979.

York, L.M., M. Griffithsand T.M. Maaz. 2022. Whole-plant phenotypic engineering: moving beyond ratios for multi-objective optimization of nutrient use efficiency. Current Opinion in Biotechnology 75:102682.

Zarei, A., V. Razban, S.E. Hosseiniand S.M.B. Tabei. 2019. Creating cell and animal models of human disease by genome editing using CRISPR/Cas9. The journal of gene medicine 21:e3082.

Zhang, Y., A.A. Malzahn, S. Sretenovicand Y. Qi. 2019. The emerging and uncultivated potential of CRISPR technology in plant science. Nature Plants 5:778-794.

Zhang, Y., K. Yun, H. Huang, R. Tu, E. Huaand M. Wang. 2021. Antisense RNA interference-enhanced CRISPR/Cas9 base editing method for improving base editing efficiency in Streptomyces lividans 66. ACS Synthetic Biology 10:1053-1063.